RECONNAISSANCE GEOPHYSICAL INVESTIGATIONS OF SALINIZATION ALONG PETRONILA CREEK (TMDL SEGMENT 2204), NUECES AND KLEBERG COUNTIES, TEXAS

by

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Contract No. 582-4-56385
Work Order No. 4

September 2004

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CONTENTS

INTRODUCTION 1

METHODS 5

RESULTS 7

Agua Dulce Creek to U.S. 77 11

Drainage Ditch Along Nueces County Road 18 12

Petronila Creek Seep Area 15

Former Pit, North Clara Driscoll Oil Field 17

AIRBORNE GEOPHYSICAL SURVEY RECOMMENDATIONS 21

CONCLUSIONS 25

ACKNOWLEDGMENTS 25

REFERENCES 26

APPENDIX. APPARENT GROUND CONDUCTIVITY MEASUREMENTS 29

FIGURES

1. Map of the Petronila Creek region 2
2. Map of the Petronila Creek study area depicting TDS concentration 3
3. Map of the Petronila Creek study area depicting chloride concentration 4
4. Geonics EM31 ground-conductivity meter 6
5. Apparent ground conductivity in the Petronila Creek area, HD mode 8
6. Apparent ground conductivity in the Petronila Creek area, VD mode 10
7. Photograph of the drainage ditch along Nueces County Road 18 13
8. Apparent ground conductivity profile along Nueces County Road 18 14
9. Photograph of apparent seep area along Petronila Creek 16
10. Apparent ground conductivity profile in the seep area, Petronila Creek 18

11. Photograph of barren area and monitor wells, North Clara Driscoll Oil Field 19
12. Apparent ground conductivity profile across barren area 20
13. Airborne geophysical survey boundaries and chloride concentrations 22
14. Airborne geophysical survey boundaries and apparent ground conductivities 23

TABLES

1. Statistical parameters for apparent ground conductivity measurements 9
2. Recommended airborne geophysical survey boundaries 24

INTRODUCTION

We used ground-based geophysical instruments to measure the apparent electrical conductivity of the ground along and near Petronila Creek, Nueces and Kleberg Counties, Texas (fig. 1), to investigate the extent and intensity of salinization degrading surface water quality in the creek. This work follows previous investigations of surface water quality by the Nueces River Authority and the Texas Commission on Environmental Quality (TCEQ, formerly TNRCC) and its subcontractors, including The Louis Berger Group and EA Engineering, Science, and Technology, resulting from the designation of Petronila Creek segment 2204 as exceeding total maximum daily load (TMDL) limits for total dissolved solids (TDS), chloride, and sulfate (EA Engineering, Science, and Technology, 2002).

Petronila Creek (and TMDL segment 2204) formally begins at the confluence of Agua Dulce Creek and Banquete Creek west of Robstown in Nueces County. It flows generally southeast for about 70 km across Nueces County and into Kleberg County, where it ultimately empties into Alazan Bay, part of the Baffin Bay estuarine complex. The creek flows in a narrow, relatively shallow valley eroded into clay-rich and sandy clay strata mapped as the Beaumont Formation (Brown and others, 1975), a late Pleistocene alluvial complex that slopes gently gulfward. Thin Holocene alluvial deposits (fine sand to clay) are present within the valley adjacent to Petronila Creek and in the streambed in places atop stiff Beaumont clay strata. Outside the valley, more recent flood and wind-blown (eolian) sediments blanket older Beaumont strata.

Recent chemical analyses of surface water in Petronila Creek, its tributaries, and in man-made ditches indicate that TDS and chloride concentrations are low upstream from the U.S. 77 bridge at Driscoll, but increase to levels that commonly exceed TMDL limits downstream from U.S. 77 (figs. 2 and 3). Possible sources of the downstream increase in salinity include (a) the presence of primary saline pore water in Beaumont Formation strata that were deposited in a late Pleistocene coastal environment; (b) salt particles blown inland and deposited by prevailing onshore winds; (c) extensive inland flooding of saline gulf and estuarine water during recurrent tropical storms; and (d) surface and near-surface discharge of saline water during hydrocarbon exploration and production, including discharge and

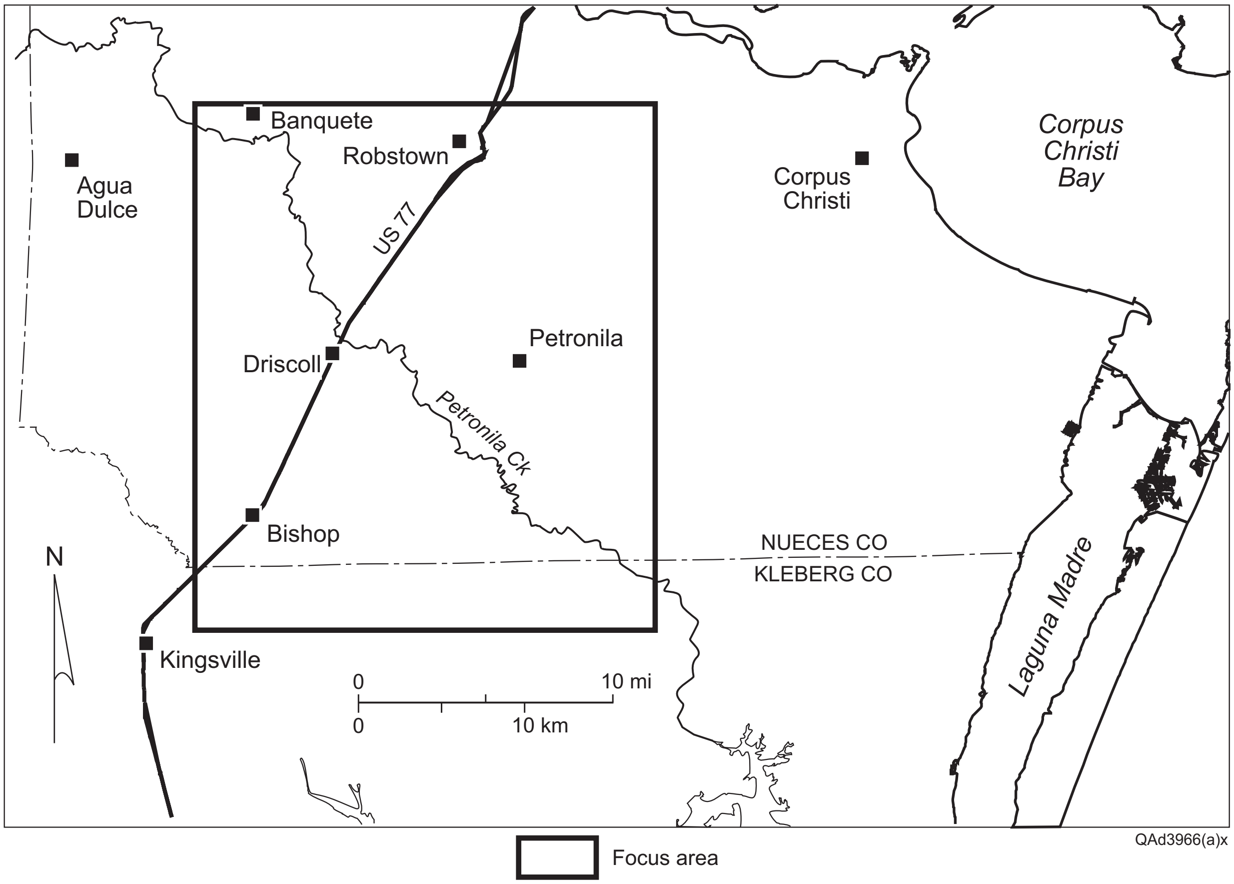

Figure 1. Map of the Petronila Creek region, Nueces and Kleberg counties, Texas.

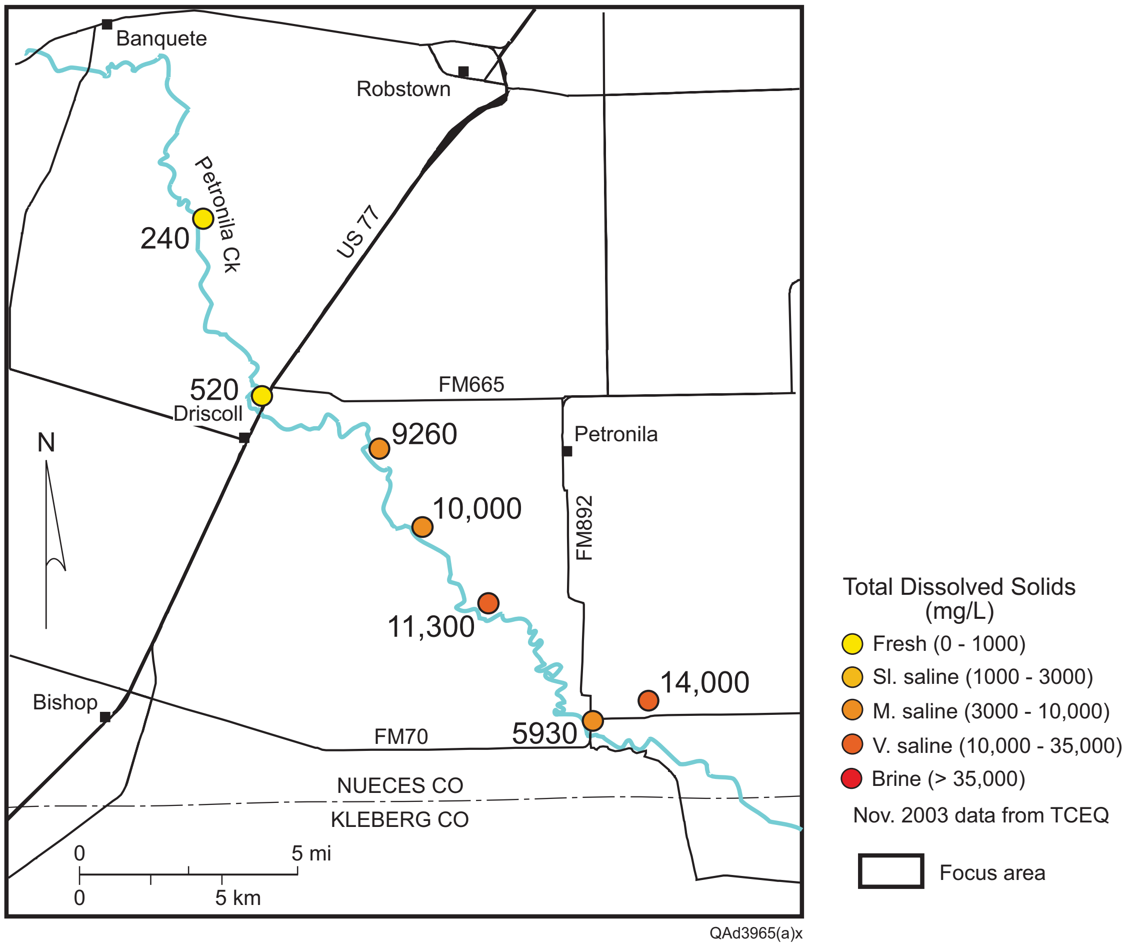

Figure 2. Map of the Petronila Creek study area depicting total dissolved solids (TDS) concentration along the creek in November 2003. TDS data from the Texas Commission on Environmental Quality (TCEQ).

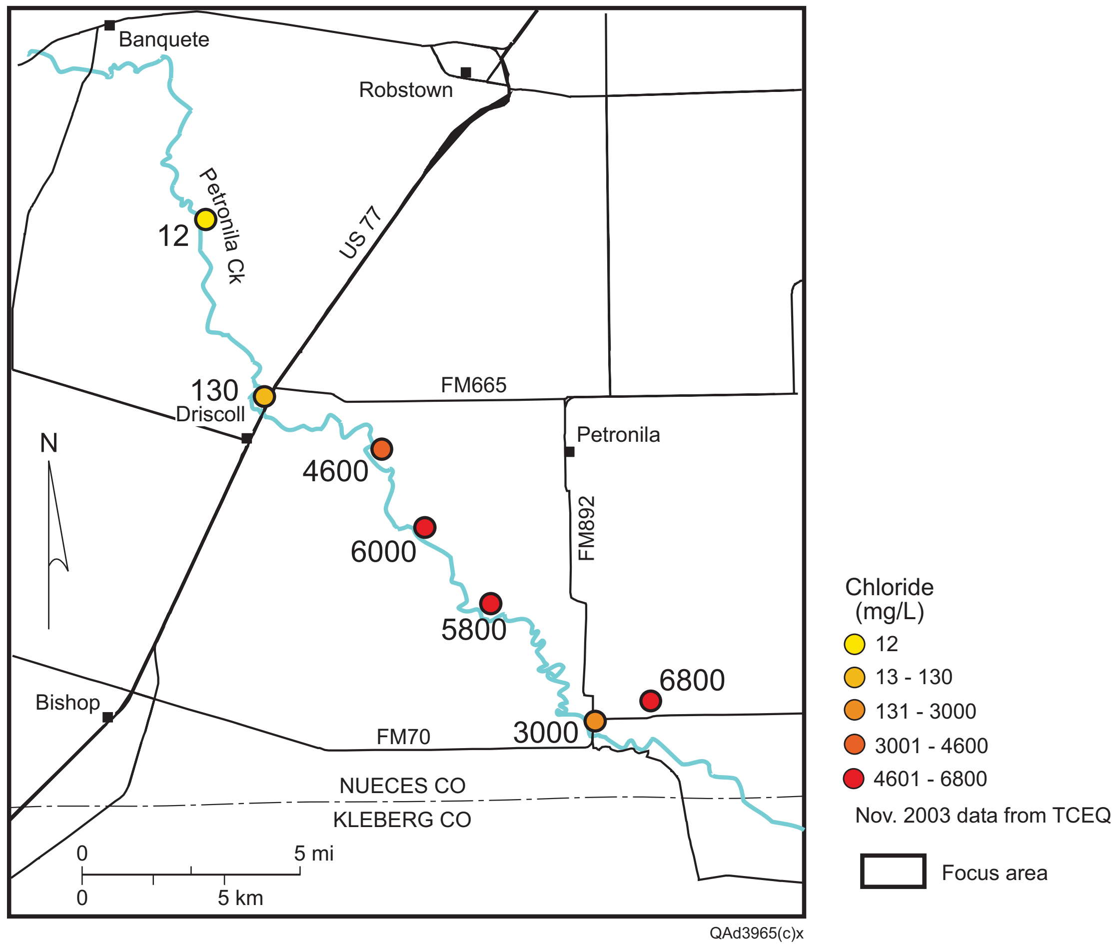

Figure 3. Map of the Petronila Creek study area depicting chloride concentration in surface-water samples along the creek in November 2003. Chloride concentration data from TCEQ.

infiltration into surface brine pits, direct discharge into creeks and ditches, and potential leaking wells. There has been significant oil and gas exploration and production activity in the study area; as of September 2001, there were 1,897 documented oil and gas wells in Nueces County (EA Engineering, Science, and Technology, 2002). Currently active fields include the Clara Driscoll and North Clara Driscoll oil fields, which are bisected by Petronila Creek.

Our goal was to use ground-based instruments to acquire ground-conductivity data that would supplement available water quality data in representative environments along and near Petronila Creek. The electrical conductivity of the ground is generally dominated by electrolytic flow of ions in pore water. Because the salinity of water is strongly correlated to its electrical conductivity (Robinove and others, 1958), the electrical conductivity of soil and sediment is also strongly influenced by the salinity of pore water. As pore-water salinity increases, so does the electrical conductivity of the ground.

METHODS

We supplemented available surface-water quality data with reconnaissance measurements of the electrical conductivity of the ground in an attempt to identify critical stream segments where highly salinized ground may contribute to the degradation of surface-water quality. Where possible, we acquired ground-conductivity measurements along the axis of main and tributary streams. If the stream axis was not accessible, we measured ground conductivity along the stream bank. At most sites, stream access was by foot from road or bridge crossings. A hand-held GPS receiver provided locations for all ground-conductivity measurements.

We used the frequency-domain electromagnetic induction (EM) method to measure apparent electrical conductivity of the ground in the study area. Frequency-domain EM methods employ a changing primary magnetic field created around a transmitter coil to induce current to flow in the ground or in the annulus around a borehole, which in turn creates a secondary magnetic field that is sensed by the receiver coil (Parasnis, 1973; Frischknecht and others, 1991; West and Macnae, 1991). The strength of the secondary field is a complex function of EM frequency and ground conductivity

(McNeill, 1980b), but generally increases with ground conductivity at constant frequency.

We used a Geonics EM31 ground conductivity meter (fig. 4) to measure the apparent conductivity of the ground. This instrument operates at a primary EM frequency of 9.8 kHz, measuring apparent conductivity to a depth of about 3 m (horizontal dipole [HD] orientation) and 6 m (vertical dipole [VD] orientation) using transmitter and receiver coils that are separated by 3.7 m. The instrument has a useful conductivity range of less than 1 millisiemens/m (mS/m) to 1,000 mS/m.

We acquired ground conductivity measurements at 166 locations along Petronila Creek, accessible tributaries, and drainage ditches that flow into Petronila Creek and across adjacent fields (appendix) between June 22 and 26, 2004. At most sites, we acquired several measurements at regular or irregular spacing depending on site accessibility.

Figure 4. Geonics EM31 ground conductivity meter measuring apparent conductivity in a drainage ditch near Driscoll, Texas.

The EM31 was calibrated at the beginning of each field day. Measurements of apparent ground conductivity were acquired by (1) placing the instrument on the ground (or holding it just above the surface of the water) in the vertical dipole orientation; (2) noting the apparent conductivity reading; (3) rotating the instrument into the horizontal dipole mode; (4) noting the apparent conductivity reading; and (5) obtaining a latitude and longitude coordinate for the measurement using the GPS receiver. All conductivity measurements were entered into a geographic information system database (ArcMap by ESRI) for analysis and comparison with water-quality data.

RESULTS

Measurements made using a ground conductivity meter in representative environments (fig. 5; appendix) show that apparent ground conductivities in the shallow subsurface are relatively high across the Petronila Creek area. In the horizontal dipole (HD) instrument orientation, where the measured value represents the apparent conductivity within the upper 3 m of the subsurface, conductivity ranged from 95 to 1065 millisiemens per meter (mS/m) and averaged 370 mS/m (table 1). Measurements taken along the creek and away from it depict a general trend of increasing apparent conductivity from northwest to southeast toward the coast. Values within the lowest conductivity category (188 mS/m or less) are found only in the northwest half of the study area (figure 5). With the exception of a single anomalously high value taken in a background area along Nueces County Road 30 (location P110, appendix), all measurements higher than 272 mS/m were located on the coastal side of U.S. 77 (fig. 5).

Measurements taken in the vertical dipole (VD) orientation, which represents apparent conductivity in the upper 6 m of the subsurface, area also relatively high across the entire study area (fig. 6; appendix).These measurements were taken at the same locations as were the HD ones, but tend to be slightly lower statistically (table 1). The average VD value is 294 mS/m, lower than the HD average of 370 mS/m. The VD range is restricted to 118 to 607 mS/m, a more limited range than that observed for the HD values. Despite the more limited range, the VD standard deviation is higher, likely reflecting the greater sensitivity of the VD measurement to powerline noise or nearby metallic debris.

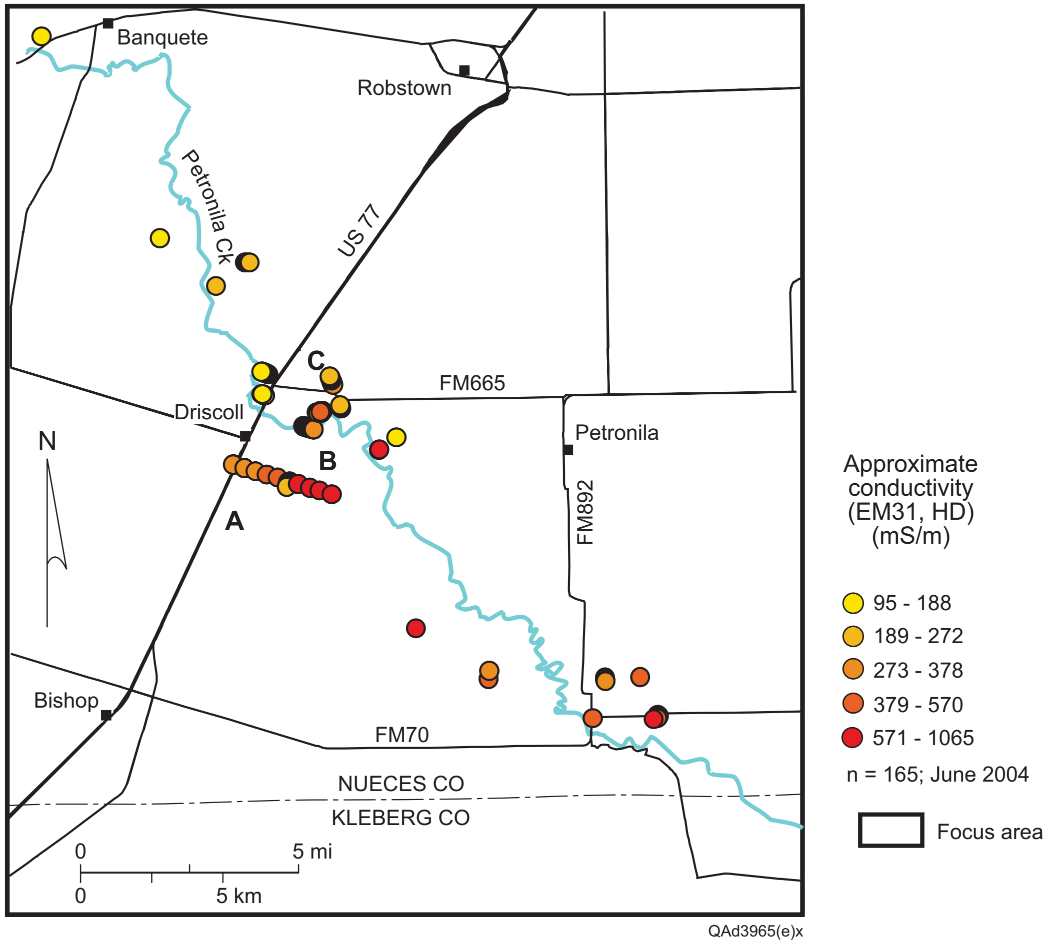

Figure 5. Apparent ground conductivity in the Petronila Creek area measured using an EM31 in the horizontal dipole (HD) mode.

Table 1. Statistical parameters for apparent ground conductivity measurements acquired in June 2004 in the Petronila Creek area, Nueces and Kleberg counties, Texas (appendix) using a Geonics EM31 instrument (fig. 4). Horizontal-dipole measurements represent the upper 3 m of the subsurface; vertical-dipole measurements represent the upper 6 m.

Instrument Orientation	Number	Average (mS/m)	Minimum (mS/m)	Maximum (mS/m)	Std. Dev. (mS/m)
Horizontal dipole	165	370	95	1065	220
Vertical dipole	165	294	118	607	294

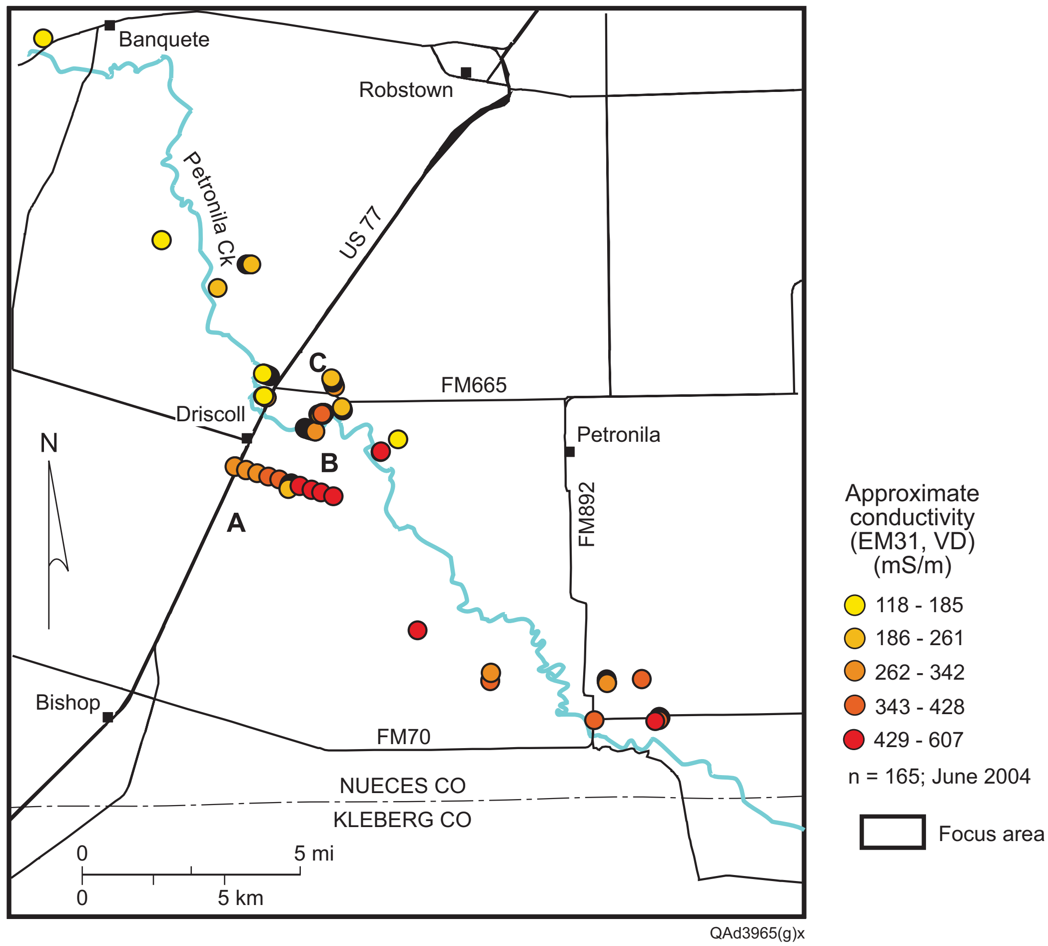

Figure 6. Apparent ground conductivity in the Petronila Creek area measured using an EM31 in the vertical dipole (VD) mode.

Apparent conductivity measured in the VD orientation also generally increases from northwest to southeast toward the coast (fig. 6). Values in the lowest category (185 mS/m or less) are all located in the northwest half of the study area. The highest values (343 mS/m or greater) are all located to the southeast of U.S. 77.

At most locations (100 of 165), the shallow (HD) measurement is greater than the deeper (VD) measurement, a relationship that is also borne out by higher average HD conductivities (table 1). In potentially salinized areas such as Petronila Creek, this relationship suggests that the sources of salinity are at or near the surface and that downward infiltration is limited.

Elevated apparent conductivities measured throughout the area are likely the combined result of (a) the presence of clayey Beaumont Formation sediments at or near the surface (Brown and others, 1975); (b) generally high moisture content in area soils; and (c) relatively high soil and sediment salinities caused by original depositional salinity, salts recently deposited by prevailing winds or inundation by saline water during storms, or discharge and migration of saline water produced from area oil and gas operations. The general gulfward increase in apparent conductivity measured in both instrument orientations suggests that regional influences (syndepositional salinity sources and modern aerosol or inundation sources) control the overall trend, while oil- and gas-field sources of produced saline water can be invoked to explain local increases in ground conductivity along and near Petronila Creek. A few more detailed examples follow.

Agua Dulce Creek to U.S. 77

The most upstream conductivity measurements were taken at Agua Dulce Creek in Sablatura Park west of Banquete (figs. 5 and 6), about 5 km upstream from the confluence with Banquete Creek and the formal upstream limit of Petronila Creek segment 2204. Conductivity values measured along Agua Dulce Creek were the lowest in the study area (95 mS/m HD and 118 mS/m VD at location P146), reflecting low water and ground salinity in this Petronila Creek tributary. Only slightly higher measurements were recorded at Pintas Creek (179 mS/m HD and 173 mS/m VD at location P104), another

Petronila Creek tributary whose confluence is about 7 km upstream from U.S. 77.

Background measurements acquired in a field along Nueces County Road 30 (CR30, figs. 5 and 6) are generally below 200 mS/m in both orientations (locations P106 to P115, appendix), lower than similar background measurements acquired at several locations southeast of U.S. 77.

Measured apparent conductivities remain low at a small impoundment along Petronila Creek about 5 km upstream from U.S. 77 (location P105, figs. 5 and 6; appendix), as well as along a profile approaching Petronila Creek at the Coastal Bend Youth City north of Driscoll (figs. 5 and 6), where measured conductivities are between 116 and 241 mS/m in both orientations (locations P064 to P077, appendix).

At the U.S. 77 bridge, apparent conductivities along Petronila Creek increase from low values upstream from the bridge (150 mS/m at P063, figs. 5 and 6; appendix) to higher values downstream from the bridge (168 to 350 mS/m in both orientations at locations P054 to P061). The general location of this increase in apparent ground conductivity coincides with the stream segment where chloride and TDS concentrations of surface-water samples also increase (figs. 2 and 3).

Drainage Ditch Along Nueces County Road 18

The drainage ditch on the north side of Nueces County Road 18 (fig. 7) crosses the Clara Driscoll Oil Field. Highly saline water has been sampled by EA Engineering, Science, and Technology, Inc. between the oil field and the point where the ditch drains into Petronila Creek (22,000 mg/L TDS concentration at station 13032 on November 20, 2003). We measured apparent ground conductivity in the floor of the ditch at approximately 400-m intervals from U.S. 77 eastward for a distance of about 4 km (area A, figs. 5 and 6).

Apparent conductivities measured in the HD and VD orientations have similar moderate values at the upstream end of the profile (from U.S. 77 to a distance of about 1.6 km downstream, fig. 8). Along this segment and farther downstream, the deeper VD values remain near 400 mS/m. In contrast, the shallower HD values show a gradual increase from 300 mS/m near U.S. 77 (location P078, appendix)

Figure 7. Photograph of the drainage ditch along Nueces County Road 18 near Driscoll.

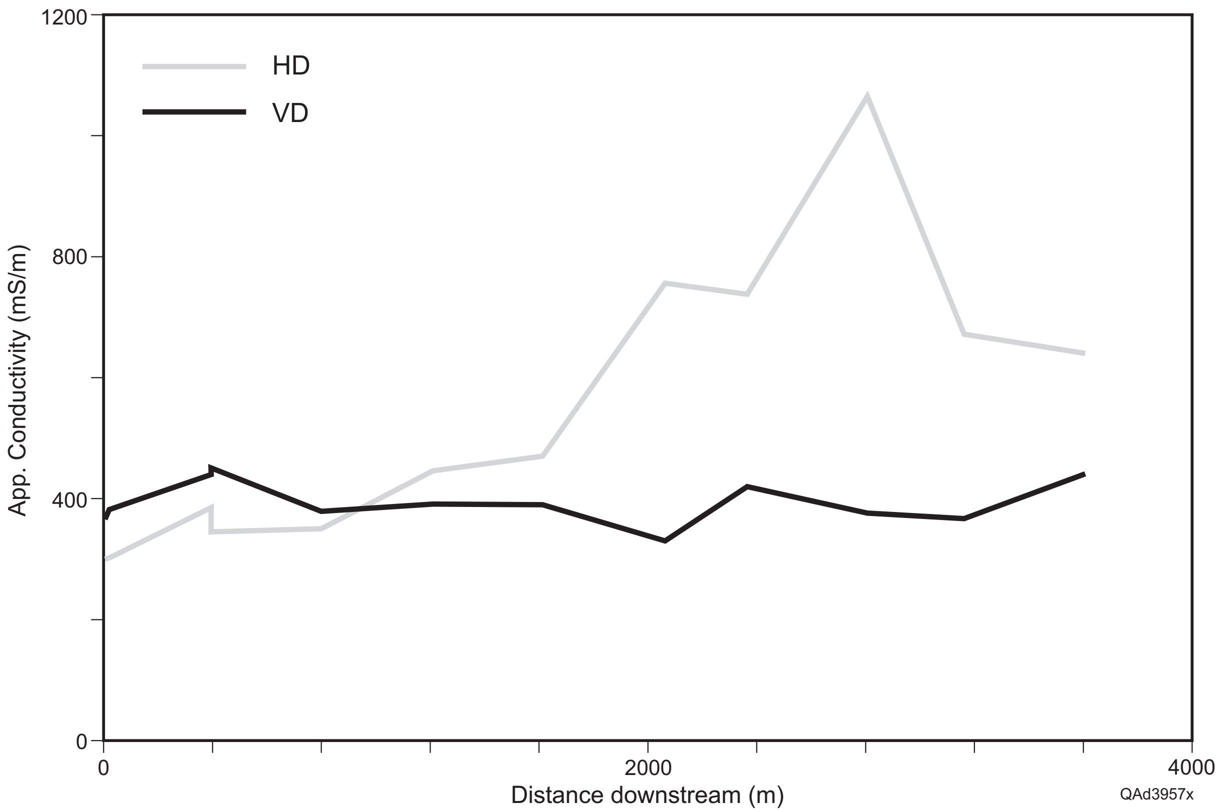

Figure 8. Apparent ground conductivity profile from west to east along the drainage ditch adjacent to County Road 18 south of Driscoll.

to 470 mS/m 1.6 km downstream (location P084), followed by a steeper increase to a peak value of 1065 mS/m (location P097) about 2.8 km downstream along the ditch. The two remaining measurement locations at the downstream end of the profile (P098 and P099) show lower but still elevated values. Station 13032 is located about 400 m farther downstream from the most downstream conductivity measurement. Background conductivity values acquired in a field adjacent to County Road 18 are significantly lower than those in the ditch, ranging from 159 to 275 mS/m in both instrument orientations (location P086 to P095, appendix).

The abrupt increase in apparent ground conductivity evident at 1.6 km from U.S. 77 suggests a local increase in ground salinity, possibly related to the spatially coincident oil field. Anomalously high HD values suggest that the salinization is restricted to the shallow zone and that downward migration is inhibited by the clay-rich Beaumont Formation substrate.

Petronila Creek Seep Area

Petronila Creek bisects the Clara Driscoll and North Clara Driscoll oil fields about 3 km northeast of Driscoll (area B, fig. 5). We acquired ground conductivity data in this area across a field away from the creek, atop the south bluff adjacent to the creek, along a short segment of the creek where saline water saturated the stream bank and a slight oil sheen was visible on standing water at the creek bottom (fig. 9), and across an abandoned well site barren of vegetation.

Measured apparent conductivity was in the moderate to low category in the presumed background area across a cultivated field northeast of Driscoll (locations P002 to P019, appendix; area B, figs. 5 and 6). Measured values along this line ranged from 195 to 247 mS/m in both orientations.

Similar low to moderate conductivities were measured in cultivated fields atop the south bluff of Petronila Creek in area B. Values along an upstream segment ranged from 195 to 290 mS/m (locations P025 to P030, appendix). Similar values (182 to 269 mS/m) were measured in a similar setting farther downstream in area B (locations P047 to P053, appendix).

Figure 9. Photograph of apparent salt-water and hydrocarbon seep area along Petronila Creek north-east of Driscoll.

In contrast to the low to moderate conductivities measured on the upland, conductivities measured in the inferred seep area along Petronila Creek (locations P031 to P038, appendix) exceed 600 mS/m in the HD orientation and 300 mS/m in the VD orientation (fig. 10). Elevated conductivities were also measured across an abandoned oil field site on the bluff above the inferred seep area (232 to 891 mS/m at locations P039 to P046, appendix). High measured conductivities at these sites suggest local salinization of the shallow subsurface that is likely to be related to oil-field activities. Higher apparent conductivities measured in the shallower HD orientation suggest limited downward infiltration of saline water into clayey Beaumont Formation strata.

Former Pit, North Clara Driscoll Oil Field

A barren area about 150 m across is located in a cultivated field in the North Clara Driscoll Oil Field about 500 m north of Petronila Creek (area C, figs. 5 and 11). According to the Railroad Commission of Texas, this is the site of a former saltwater separation pond (F. Munoz, pers. comm., 2004) that has been abandoned and filled. Multiple shallow monitoring wells have been installed in the barren area and in the surrounding cultivated field (fig. 11). We acquired apparent conductivity measurements along a profile line that crossed the barren area approximately north–south and extended beyond the barren area into the cultivated field to the north and south (fig. 12; locations P147 to 178, appendix).

Apparent conductivities area higher across the barren area in both instrument orientations. In the shallower HD mode, apparent conductivities exceed 400 mS/m across the entire barren area and reach a peak value of 963 mS/m near the center of the barren area (fig. 12). Outside of the barren area, apparent conductivity remains higher to the south (downslope toward Petronila Creek) than it does to the north in both the shallower HD and deeper VD orientations. The HD measurements reach likely background values of less than 275 mS/m north of the barren area. Elsewhere along the profile, HD values are higher than VD values, suggesting shallow salinity sources with limited downward infiltration.

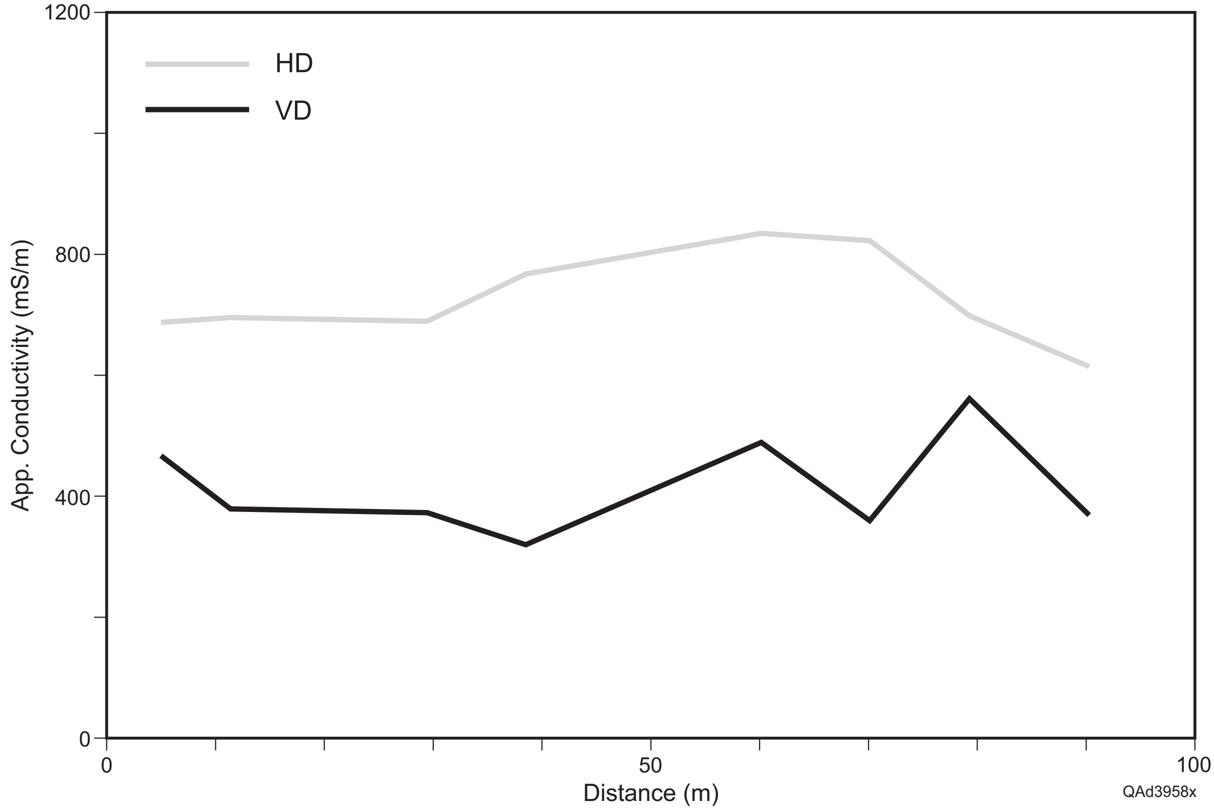

Figure 10. Apparent ground conductivity profile in the seep area along Petronila Creek.

Figure 11. Photograph of barren area and monitor wells in the North Clara Driscoll Oil Field.

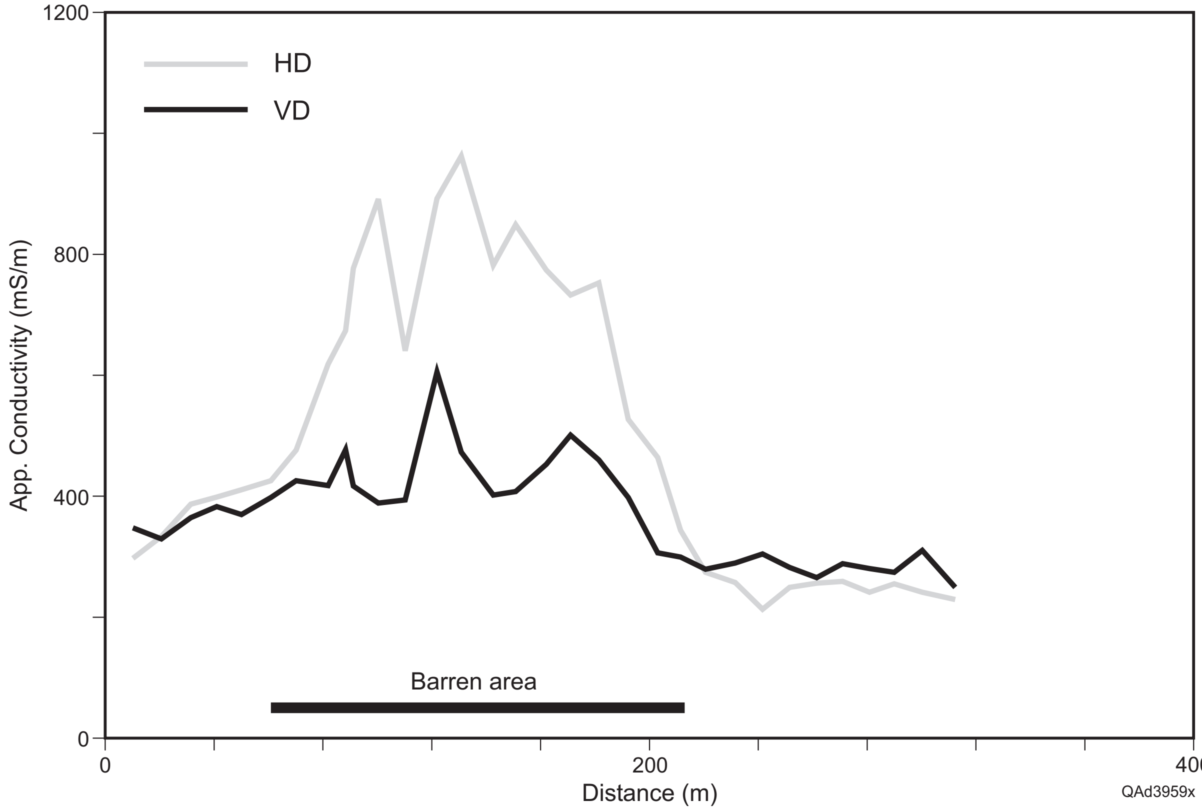

Figure 12. Apparent ground conductivity profile from south to north across the barren area in the North Clara Driscoll Oil Field.

AIRBORNE GEOPHYSICAL SURVEY RECOMMENDATIONS

Except for limited stream and ditch crossings along public roads, only a small portion of Petronila Creek and its tributaries is accessible by ground. Reconnaissance ground-based measurements supplemented available water-quality data and confirmed that little potential for salinization exists upstream from U.S. 77, but that significant salinization of Petronila Creek occurs within a short distance of U.S. 77 and continues to the most downstream segment surveyed. Local areas of elevated ground conductivity suggest that there are local sources of salinization that degrade surface water quality, including several sites near Driscoll and within the Driscoll Oil Field area. An airborne geophysical survey can be expected to reveal information on the location and lateral and vertical extent of salinized ground and its relationship to Petronila Creek and its tributaries more rapidly and in more detail than could be achieved with ground-based instruments.

For this area, the most useful airborne survey would be one in which a multi-frequency EM instrument is towed over a gridded survey area by helicopter. The multi-frequency EM instrument acquires data on the apparent conductivity of the ground to several exploration depths simultaneously, allowing users to interpret the lateral extent of conductivity anomalies at given frequencies as well as to interpret whether salinization arises from surface or subsurface sources. If the helicopter also tows a magnetometer, local variations in magnetic field strength can be identified that correspond to potentially significant features such as wells and pipelines.

The preferred survey corridor is a 150-km^2 rectangle with its long dimension parallel to the axis of Petronila Creek (figs. 13 and 14). The survey area is 6 km wide and 25 km long, extending from just upstream of U.S. 77 to the northern limit of Kleberg County (table 2). Assuming a northwest-southeast principal flight line orientation and 200-m line spacing, total flight distance will be about 825 km. Similar flight distances (and survey cost) could be achieved by reducing the length of the rectangle if closer flight-line spacing is required in the Driscoll area.

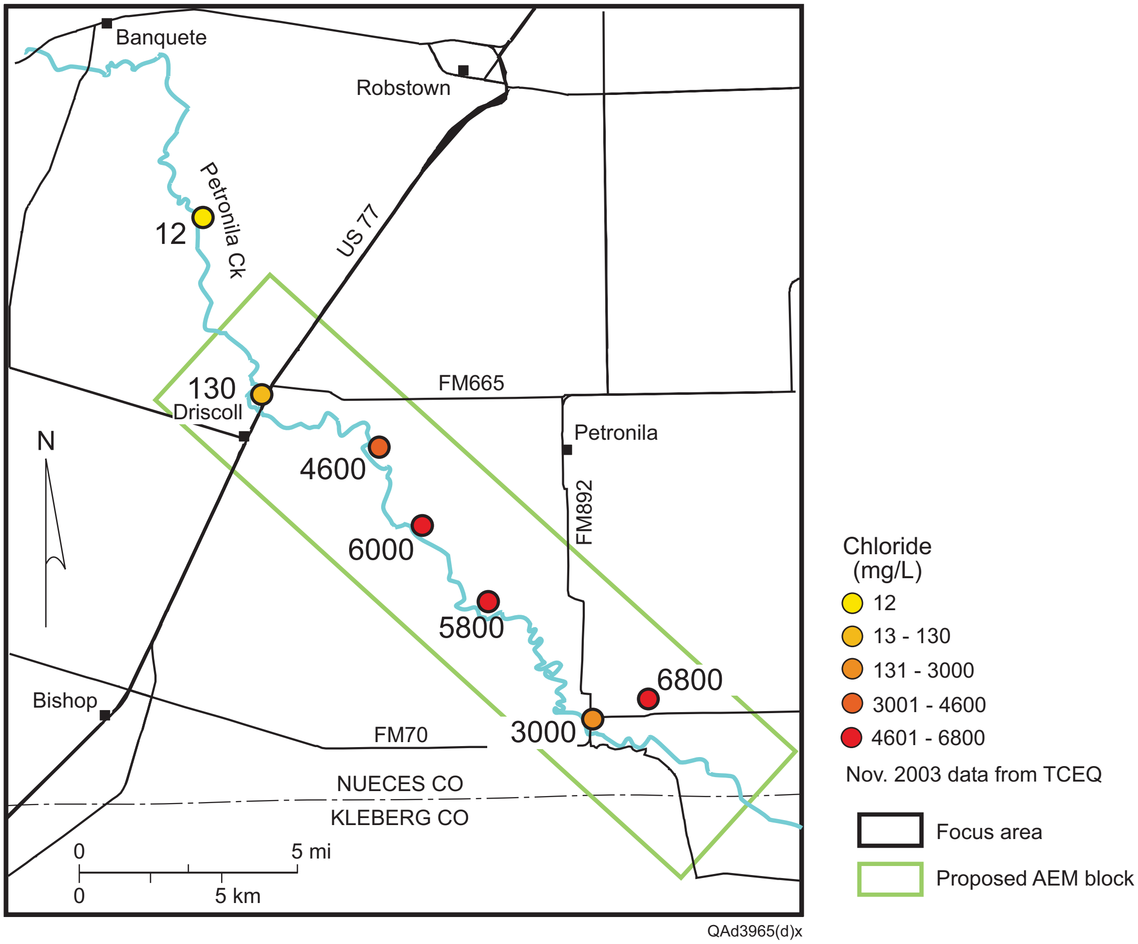

Figure 13. Relationship between recommended airborne survey boundaries and chloride concentrations in surface water. Chloride concentrations from TCEQ.

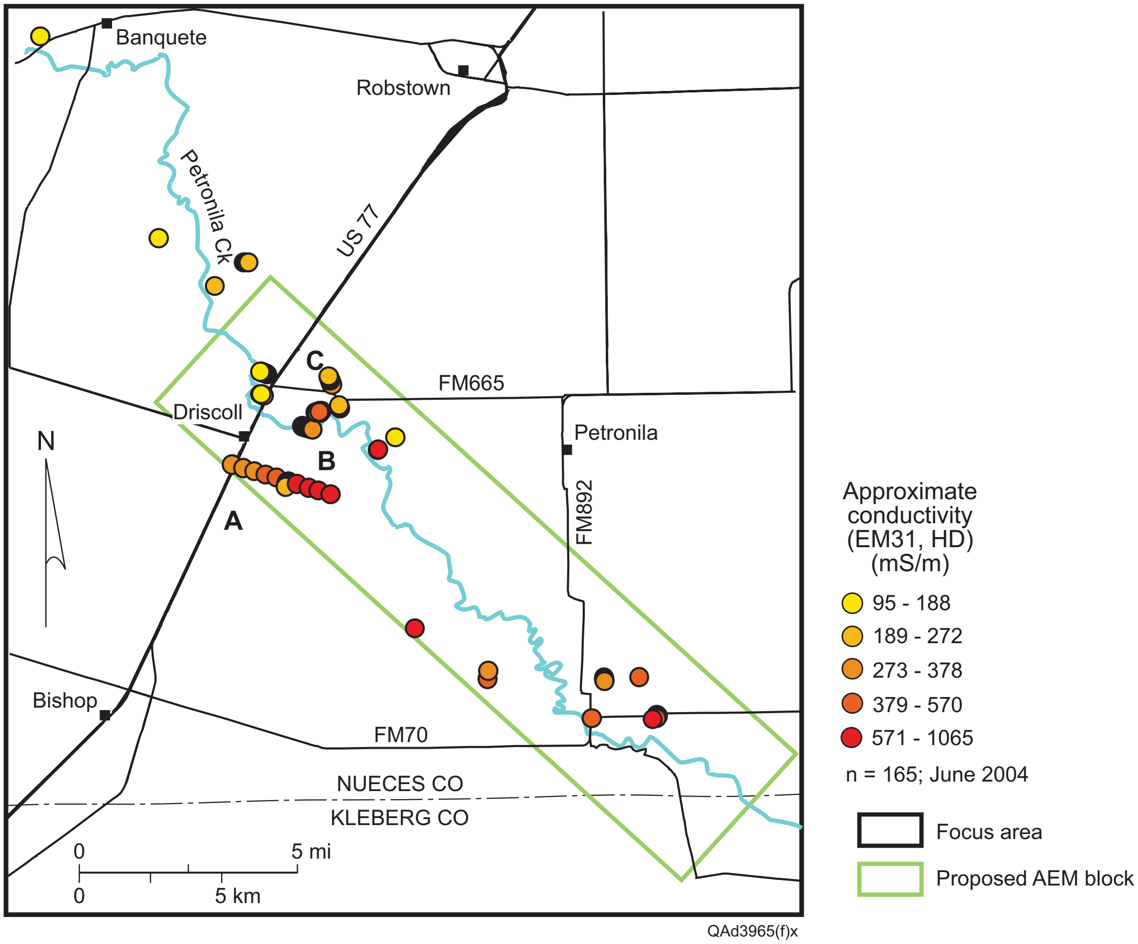

Figure 14. Relationship between recommended airborne survey boundaries and apparent ground conductivities in the HD mode in the Petronila Creek area.

Table 2. Recommended airborne geophysical survey boundaries (figs. 13 and 14) for the Petronila Creek area. Corner coordinates are easting and northing values in the Universal Transverse Mercator projection, Zone 14 North, WGS 1984 datum, in meters.

Corner	Northing	Easting
Northeast	3050059	642788
Northwest	3066857	624273
Southeast	3045615	638756
Southwest	3062416	620236

CONCLUSIONS

Reconnaissance measurements of the electrical conductivity of the ground in the Petronila Creek area confirm the presence of highly conductive areas indicative of near-surface salinization that may contribute to degradation of Petronila Creek water quality. These measurements suggest that no significant sources of salinization affect the creek upstream from U.S. 77, but that significant salinization of the creek begins near the U.S. 77 bridge and extends to at least the FM 70 bridge crossing near the Kleberg County line.

Measurements made in both "background" areas and along the stream show a regional pattern of lower conductivity to the northwest and higher conductivity to the southeast. Superimposed on this regional pattern, which is likely due to regional influences such as flooding frequency, moisture content, clay content, and aerosol salt concentrations, are local conductivity highs along and near the creek that spatially coincide with oil-field development. This coincidence suggests that past discharge of produced water in surface pits, ditches, drainages, and leaking wells has contributed to the degradation of water quality along Petronila Creek.

An airborne geophysical survey over a critical portion of Petronila Creek would provide rapid, laterally continuous measurements of electrical conductivity at multiple exploration depths over areas that are inaccessible on the ground. These measurements would enable users to identify significant areas of salinization that are likely to impact water quality in Petronila Creek as well as help determine sources of salinity within the survey area.

ACKNOWLEDGMENTS

This project was funded under Service Order No. 4, Framework Agreement No. 582-4-56385 between the Texas Commission on Environmental Quality (TCEQ) and the Bureau of Economic Geology, The University of Texas at Austin, Jeffrey G. Paine, principal investigator. Kerry Niemann served as TCEQ's project manager.

Fermin Munoz of the Texas Railroad Commission (Director, District 4) and Rocky Freund of the Nueces River Authority helped guide field investigations and provided water-quality data, Raed El-Farhan and Robert Oakes of The Louis Berger Group provided GIS data, Deborah Flados of the Texas Railroad Commission provided oil and gas well data, and Mark Kelly of EA Engineering, Science, and Technology provided guidance on field conditions in the Petronila Creek area. Steve Walden facilitated the project and reviewed work plans and deliverables.

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APPENDIX: APPARENT GROUND CONDUCTIVITY MEASUREMENTS

Apparent conductivity measured in the Petronila Creek area, June 22 to 26, 2004. Conductivities (in millisiemens per meter, or mS/m) were measured using the Geonics EM31 ground conductivity meter in the vertical (VD) and horizontal (HD) dipole configurations. Location coordinates, determined using a GPS receiver, are in decimal degrees using the 1984 World Geodetic System (WGS 1984).

Location	**Latitude (degrees)**	**Longitude (degrees)**	**App. Con. (VD, mS/m)**	**App. Con (HD, mS/m)**	**Notes**
P002	27.67303	-97.72922	219	195	Edge of field east of Driscoll
P003	27.67298	-97.72904	209	226	“
P004	27.67293	-97.72884	221	236	“
P005	27.67289	-97.72864	212	221	“
P006	27.67283	-97.72845	233	233	“
P007	27.67278	-97.72826	226	223	“
P008	27.67272	-97.72806	226	223	“
P009	27.67267	-97.72787	244	231	“
P010	27.67263	-97.72767	222	224	“
P011	27.67257	-97.72748	208	220	“
P012	27.67252	-97.72729	209	225	“
P013	27.67246	-97.72709	230	237	“
P014	27.67241	-97.72690	231	238	“
P015	27.67235	-97.72670	226	230	“
P016	27.67230	-97.72650	212	213	“
P017	27.67224	-97.72630	217	214	“
P018	27.67219	-97.72612	247	237	“
P019	27.67213	-97.72593	240	247	“
P020	27.67208	-97.72574	257	268	“
P021	27.67203	-97.72556	261	286	“
P022	27.67198	-97.72541	304	317	Center of dirt road
P025	27.67737	-97.72430	233	202	Field adjacent to Petronila Creek
P026	27.67734	-97.72421	232	195	“
P027	27.67731	-97.72412	244	211	“
P028	27.67728	-97.72402	259	247	“
P029	27.67727	-97.72393	290	272	“
P030	27.67723	-97.72382	290	264	“
P031	27.67777	-97.72308	469	689	Petronila Creek; oilfield site
P032	27.67780	-97.72297	381	697	“
P033	27.67781	-97.72279	375	691	“
P034	27.67782	-97.72270	322	769	“
P035	27.67779	-97.72248	491	836	“
P036	27.67777	-97.72238	362	824	“
P037	27.67781	-97.72228	563	700	“
P038	27.67780	-97.72218	371	616	“
P039	27.67764	-97.72291	291	555	Well site above Petronila Creek
P040	27.67758	-97.72285	393	770	“
P041	27.67748	-97.72282	395	891	“
P042	27.67740	-97.72280	399	889	“
P043	27.67730	-97.72277	288	430	“

P044	27.67722	-97.72274	232	570	“
P045	27.67716	-97.72271	260	238	“
P046	27.67747	-97.72306	417	542	Well site; dry ponded area
P047	27.67865	-97.71568	257	269	Dirt road adjacent to Petronila Creek
P048	27.67883	-97.71572	209	210	“
P049	27.67900	-97.71577	182	197	“
P051	27.67918	-97.71584	196	216	“
P052	27.67935	-97.71591	207	221	“
P053	27.67952	-97.71597	197	247	“
P054	27.68316	-97.74339	202	168	Petronila Creek; downstream from U.S. 77
P055	27.68312	-97.74329	205	177	“
P056	27.68298	-97.74321	272	235	“
P057	27.68297	-97.74317	278	241	“
P058	27.68289	-97.74310	269	283	“
P059	27.68287	-97.74297	275	314	“
P060	27.68286	-97.74288	327	290	“
P061	27.68280	-97.74283	283	350	“
P062	27.68325	-97.74402	203	250	Petronila Creek; at U.S. 77 bridge
P063	27.68324	-97.74368	150	150	“
P064	27.68960	-97.74160	203	199	Field south of Coastal Bend Youth City
P065	27.68967	-97.74178	211	183	“
P066	27.68976	-97.74198	209	171	“
P067	27.68983	-97.74215	193	170	“
P068	27.68992	-97.74232	182	165	“
P069	27.69000	-97.74252	184	155	“
P070	27.69007	-97.74271	201	154	“
P071	27.69017	-97.74287	206	188	“
P072	27.69023	-97.74306	230	241	“
P073	27.69031	-97.74325	219	210	“
P074	27.69037	-97.74345	172	196	“
P075	27.69044	-97.74362	143	152	“
P076	27.69051	-97.74381	122	125	“
P077	27.69056	-97.74401	131	116	“
P078	27.66105	-97.75422	366	300	Ditch along County Road 18
P079	27.66113	-97.75441	382	302	“
P080	27.65993	-97.75041	440	385	“
P081	27.65996	-97.75041	451	345	“
P082	27.65889	-97.74649	379	350	“
P083	27.65780	-97.74250	391	446	“
P084	27.65675	-97.73860	390	470	“
P085	27.65550	-97.73425	330	756	“
P086	27.65541	-97.73482	258	242	Along dirt road south of County Road 18
P087	27.65522	-97.73486	245	275	“
P088	27.65505	-97.73493	159	197	“
P089	27.65490	-97.73499	228	230	“
P090	27.65472	-97.73503	216	215	“
P091	27.65456	-97.73514	250	233	“
P092	27.65435	-97.73517	237	226	“
P093	27.65419	-97.73521	218	229	“
P094	27.65403	-97.73526	216	221	“
P095	27.65389	-97.73534	201	206	“
P096	27.65471	-97.73132	420	738	Ditch along County Road 18
P097	27.65342	-97.72709	376	1065	“
P098	27.65256	-97.72361	367	672	“

P099	27.65130	-97.71934	441	640	“
P101	27.66908	-97.69605	167	165	Ditch along FM 665
P102	27.66517	-97.70230	276	796	Petronila Creek at FM 665
P103	27.66535	-97.70226	455	700	“
P104	27.73338	-97.77972	173	179	Pintas Creek
P105	27.71788	-97.75979	160	192	Petronila Creek
P106	27.72529	-97.74949	184	151	County Road 30
P107	27.72528	-97.74929	182	154	“
P108	27.72528	-97.74908	185	152	“
P109	27.72525	-97.74888	170	135	“
P110	27.72525	-97.74868	273	396	“
P111	27.72525	-97.74848	153	158	“
P112	27.72526	-97.74828	123	115	“
P113	27.72525	-97.74808	128	145	“
P114	27.72525	-97.74786	149	112	“
P115	27.72526	-97.74767	144	191	“
P116	27.59213	-97.60996	345	470	Unnamed tributary to Petronila Creek
P117	27.57916	-97.62711	402	450	Petronila Creek at old FM 70 crossing
P118	27.57969	-97.60368	408	403	Lease road south of FM 70
P119	27.57986	-97.60377	324	494	“
P120	27.58002	-97.60395	315	280	“
P121	27.57949	-97.60402	421	448	Road to Petronila Creek
P122	27.57932	-97.60404	371	385	“
P123	27.57912	-97.60407	365	400	“
P124	27.57895	-97.60411	338	391	“
P125	27.57867	-97.60533	416	615	Petronila Creek
P127	27.59209	-97.62249	417	408	Dirt road south of County Road 10
P128	27.59192	-97.62248	253	414	“
P129	27.59173	-97.62250	386	400	“
P130	27.59156	-97.62249	393	418	“
P131	27.59137	-97.62250	381	378	“
P132	27.59120	-97.62249	355	354	“
P133	27.59101	-97.62249	342	342	“
P134	27.59083	-97.62249	352	354	“
P135	27.59218	-97.66414	337	410	Unnamed creek/ditch
P136	27.59207	-97.66404	296	411	“
P137	27.59457	-97.66393	298	295	“
P138	27.60832	-97.68988	402	735	Ditch at FM 3354
P146	27.79769	-97.82130	118	95	Agua Dulce Creek at park
P147	27.68735	-97.71901	410	850	Barren area traverse; center point
P148	27.68727	-97.71899	404	783	Barren area traverse
P149	27.68717	-97.71895	475	963	“
P150	27.68709	-97.71894	607	893	“
P151	27.68700	-97.71890	396	642	“
P152	27.68691	-97.71886	391	892	“
P153	27.68684	-97.71881	419	778	“
P154	27.68681	-97.71881	479	675	“
P155	27.68676	-97.71876	420	620	“
P156	27.68667	-97.71872	428	478	“
P157	27.68659	-97.71867	400	428	South edge of barren area
P158	27.68651	-97.71864	372	413	Barren area traverse
P159	27.68643	-97.71862	385	401	“
P160	27.68634	-97.71859	367	389	“
P161	27.68625	-97.71855	332	336	“

P162	27.68616	-97.71852	350	300	“
P163	27.68743	-97.71906	455	775	“
P164	27.68751	-97.71910	503	734	“
P165	27.68760	-97.71913	462	754	“
P166	27.68769	-97.71917	400	529	“
P167	27.68778	-97.71921	309	466	“
P168	27.68786	-97.71920	302	346	North edge of barren area
P169	27.68795	-97.71923	282	277	Barren area traverse
P170	27.68802	-97.71929	292	260	“
P171	27.68810	-97.71936	307	216	“
P172	27.68818	-97.71941	285	252	“
P173	27.68827	-97.71942	268	259	“
P174	27.68836	-97.71945	291	262	“
P175	27.68843	-97.71949	283	244	“
P176	27.68852	-97.71952	277	258	“
P177	27.68860	-97.71956	313	244	“
P178	27.68871	-97.71956	252	232	“